Future Directions for Advanced Computing Infrastructure

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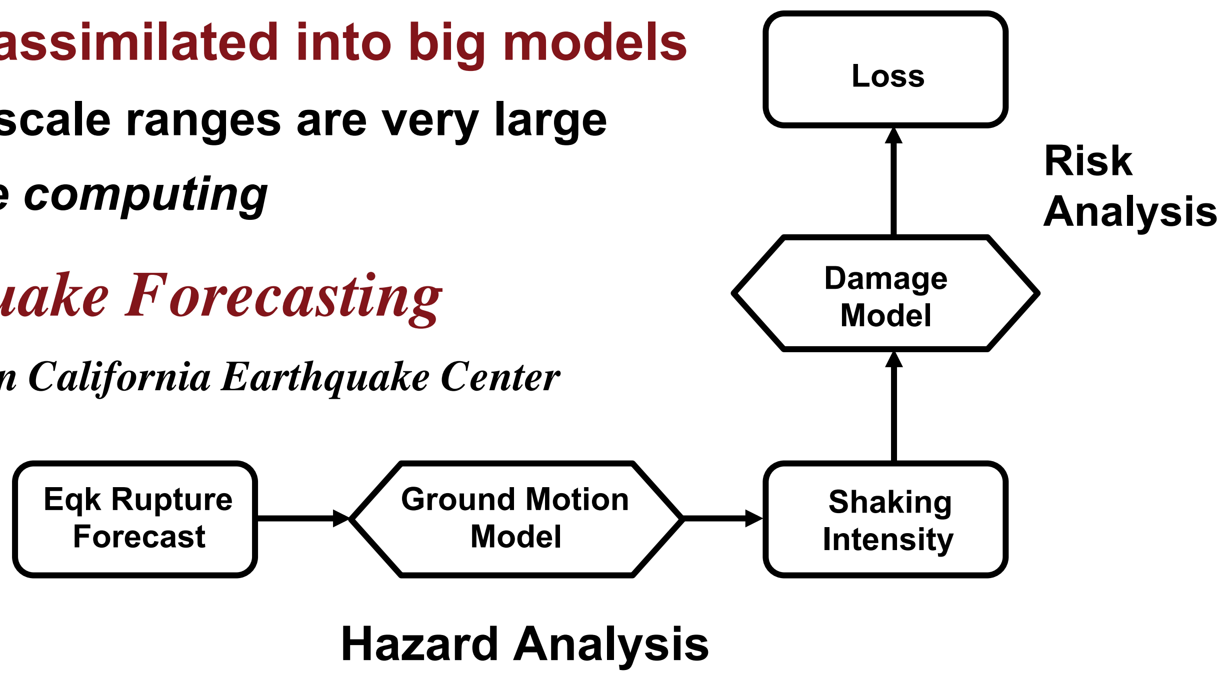
Geosystem Science

- **Model-based studies of complex natural systems**
  - System model defined to represent specific natural behaviors
    ⇒ *problems are 'top-down'*
- **Forecasting behaviors requires probabilistic models**
  - Need to represent the aleatory variability of nature but also the epistemic uncertainty in our understanding of nature
    ⇒ *large model ensembles*
- **Big data must be assimilated into big models**
  - Spatiotemporal scale ranges are very large
    ⇒ *extreme-scale computing*
- **Example: *Earthquake Forecasting***
  - *Research by Southern California Earthquake Center*



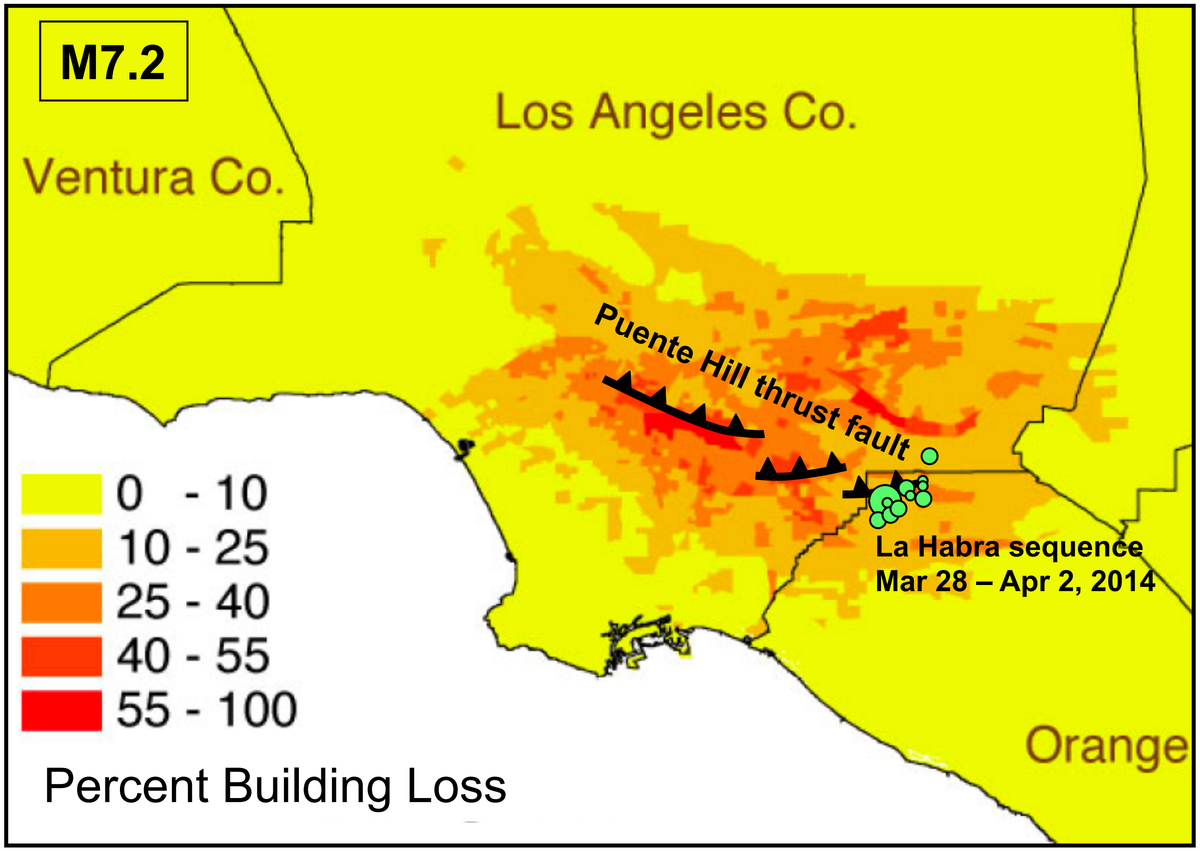
Puente Hills Earthquake Scenarios

(Magnitude 7.1 to 7.5)

"Earthquake from Hell"

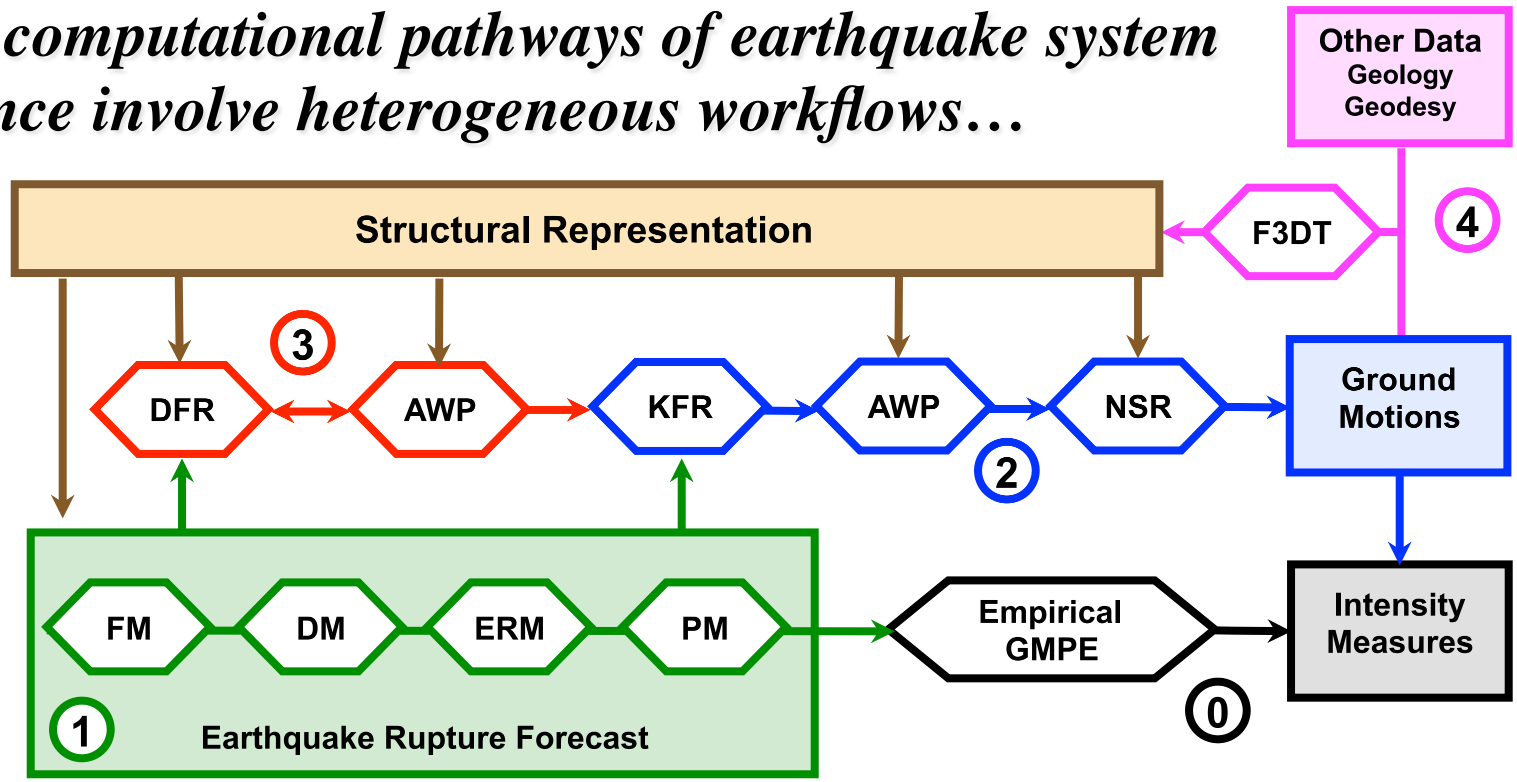
Projected losses

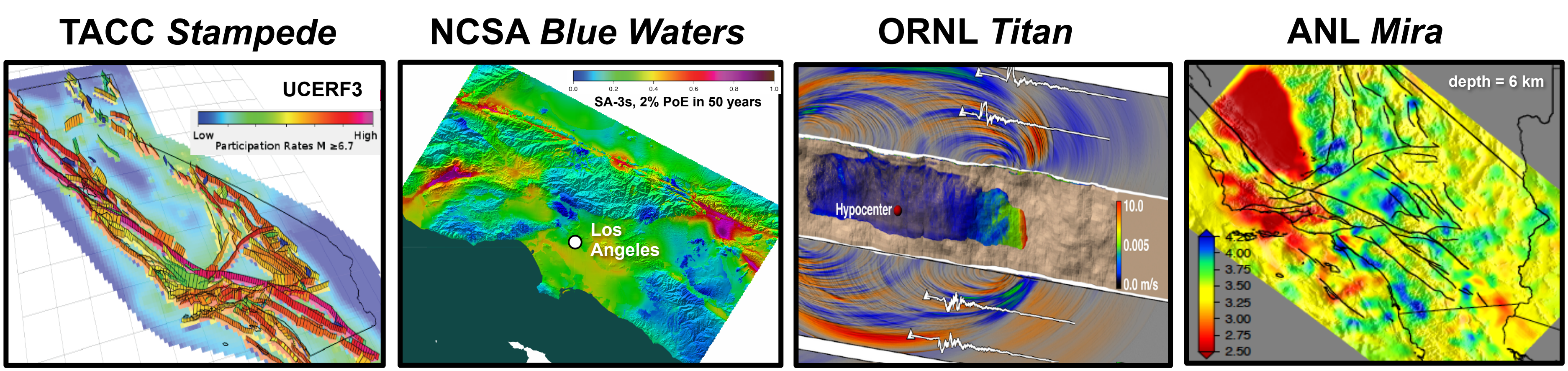
$82 B - $252 B
3,000 - 18,000 fatalities
142,000 - 735,000 displaced households
30,000 - 99,000 tons of debris



Loss estimation by Field et al. (2005)

The computational pathways of earthquake system science involve heterogeneous workflows…





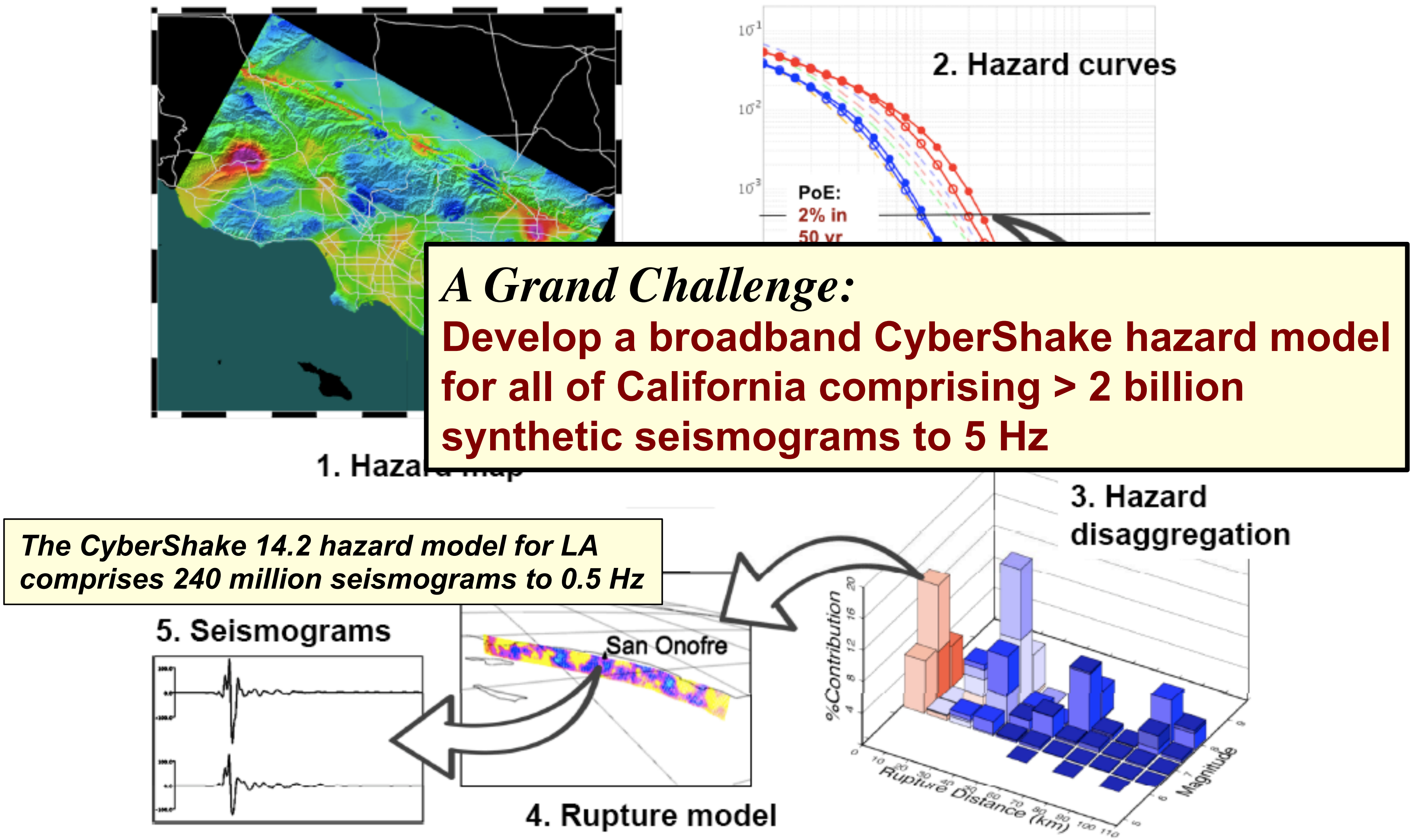
1 Uniform California Earthquake Rupture Forecast (UCERF3)

2 CyberShake 14.2 seismic hazard model for LA region

3 Dynamic rupture model of fractal roughness on SAF

4 Full-3D tomographic model CVM-S4.26 of S. California

CyberShake Platform has provided physics-based seismic hazard models for the LA region with many layers of accessible information…



A Grand Challenge:

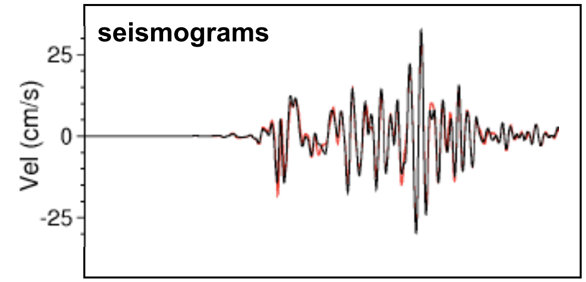
Develop a broadband CyberShake hazard model for all of California comprising > 2 billion synthetic seismograms to 5 Hz

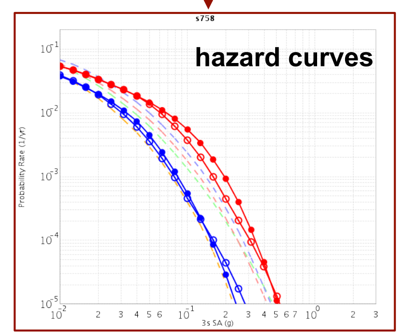
The CyberShake 14.2 hazard model for LA comprises 240 million seismograms to 0.5 Hz

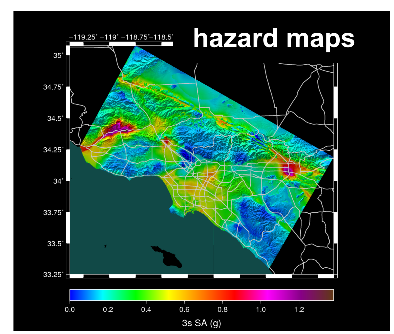
CyberShake Workflow

UCVM → **AWP-ODC** → **SeisSynth** →

UCVM	AWP-ODC	SeisSynth
Mesh generation	*SGT computation*	*Post-processing*
1 job per site	**2 jobs per site**	**415,000 jobs per site**







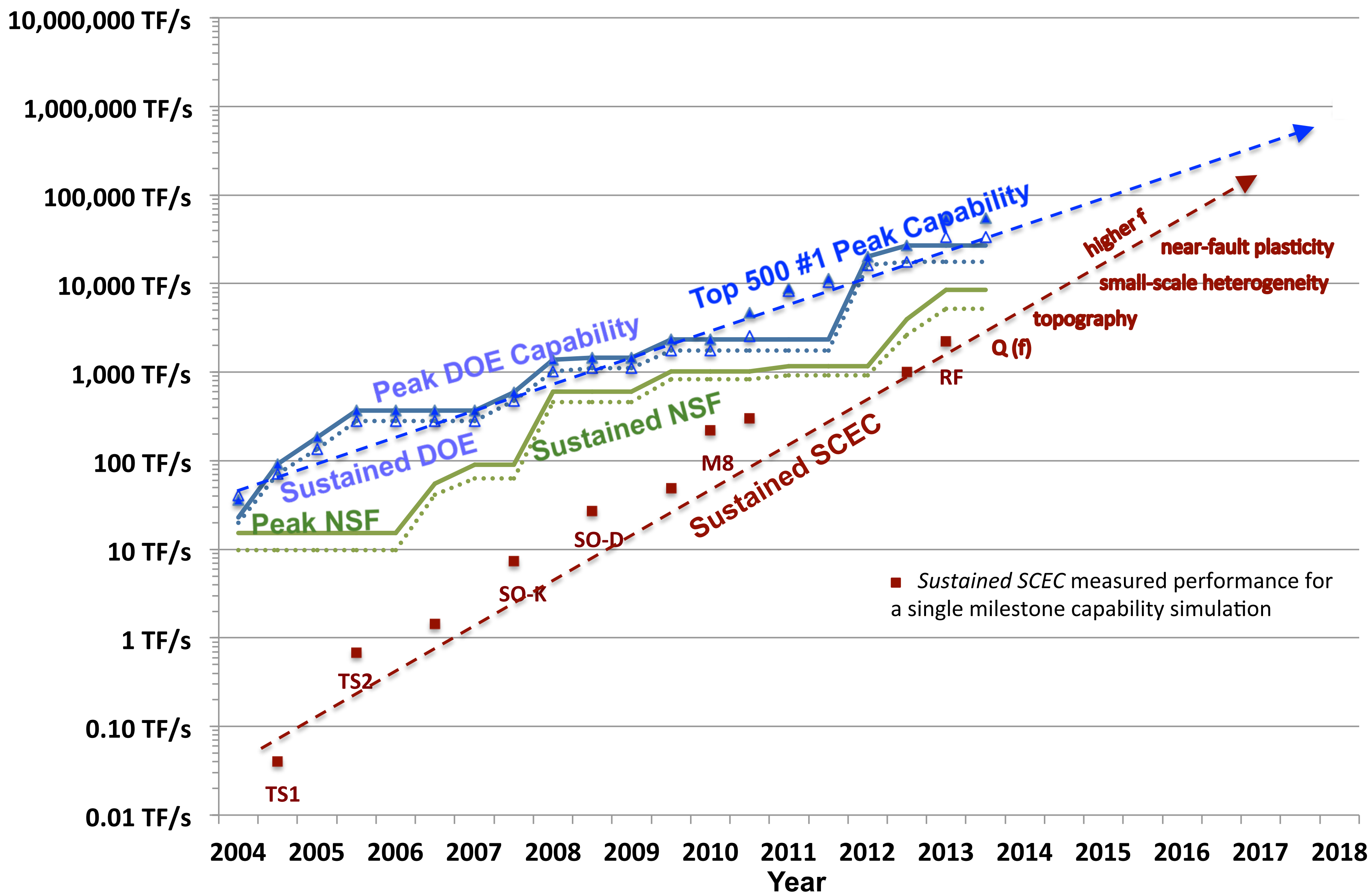
Los Angeles Region Hazard Model (283 sites)

CyberShake Application Metrics (Hours):	2008 (Mercury)	2009 (Ranger)	2013 (Blue Waters/ Stampede)	2014 (Blue Waters)
Application Core Hours:	19,448,000	16,130,400	12,200,000	10,000,000
Application Makespan:	70,165	6,191	1,467	342
Application Time to Solution:	72,493	8,519	3,795	2,670

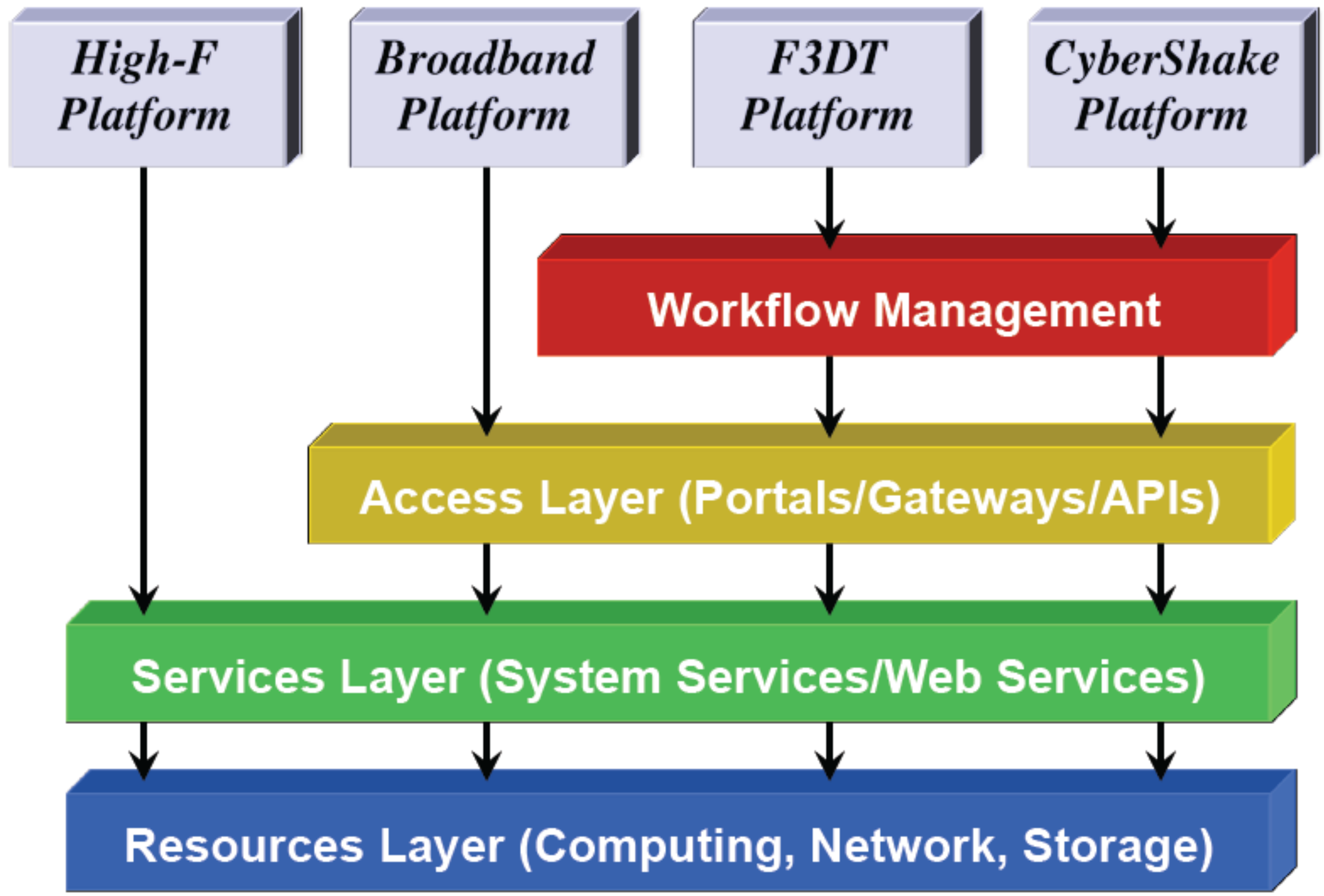
Challenges:

- **higher frequencies (0.5 Hz → 5 Hz)**
- **better physics (near-fault & site nonlinearities)**
- **more sites (1440 for statewide)**

The SCEC Community needs extreme-scale computing…



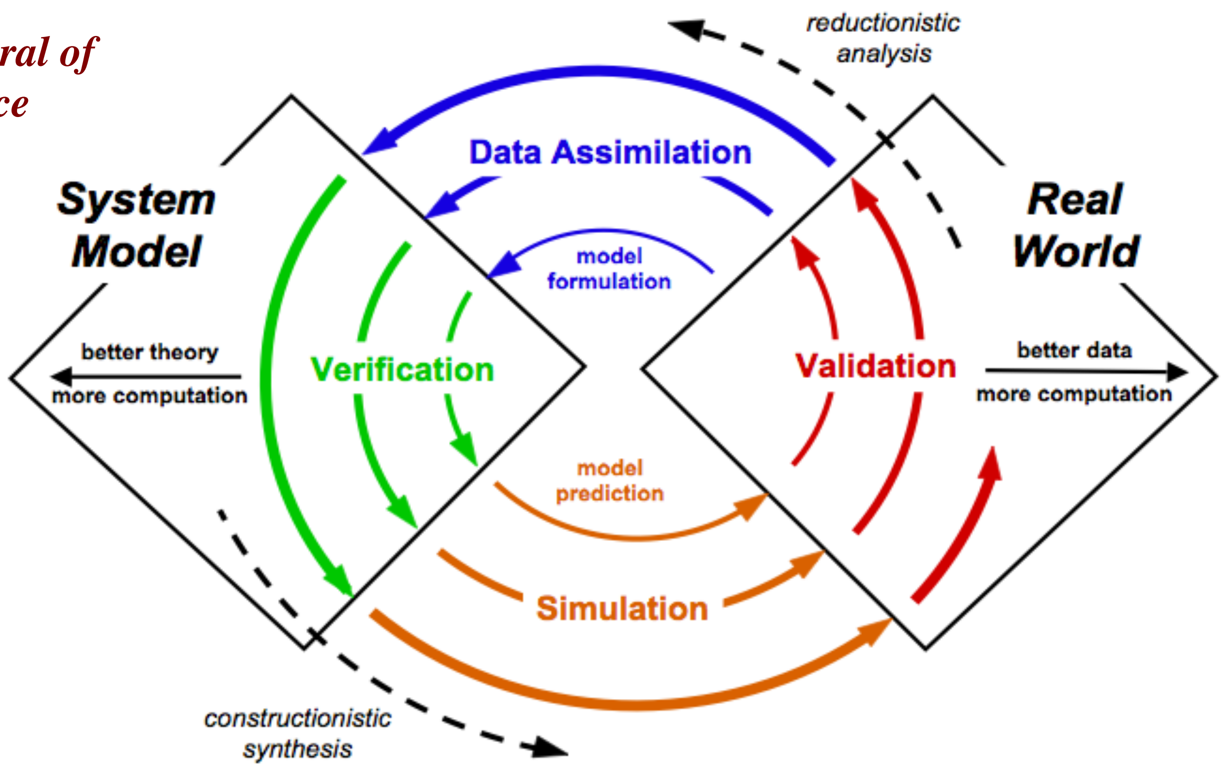
Geosystem science drives the vertical integration of CI layers…



SCEC needs reflect the broader HPC requirements of geosystem science…

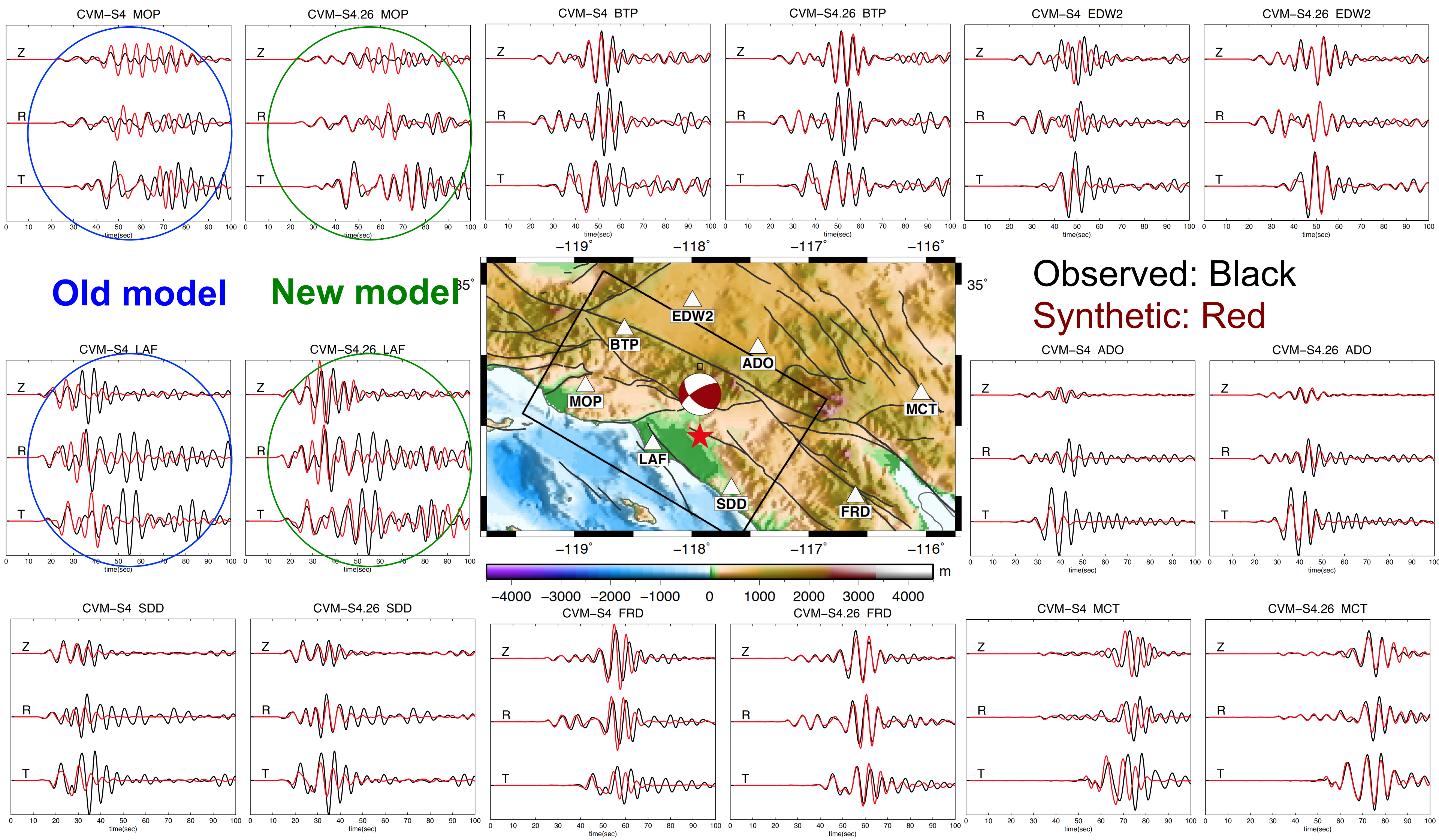
- **Geosystem science requires an iterative, computationally intense process of model formulation and verification, simulation-based predictions, validation against observations, and data assimilation to improve the model**

Inference Spiral of System Science



- **As models become more complex and new data bring in more information, geosystem science requires ever increasing computational resources**

Validation of CyberShake wave-propagation model using the 03/28/14 La Habra Earthquake (M5.1)…



Current Procedures for Gathering HPC Resources

Scientific collaborations must compete for HPC resources through a complex series of proposals and negotiations:

1. **Research funding**
   - **through NSF programs in GEO and CISE**
2. **Allocation of cycles**
   - **through NSF XSEDE & PRAC, DOE INCITE**
3. **Allocation of storage**
   - **run-time storage through (2); extended storage by negotiation with HPC centers**
4. **Allocation of software engineers**
   - **formal proposals (e.g. XSEDE) and informal negotiations with HPC centers**

Recommendations

1. NSF programs to sustain deep collaborations among geoscientists and computational scientists focused on extreme-scale computing in solid-Earth science

2. Coherent processes for the allocation of HPC cycles and storage that are coordinated with NSF science funding

3. Support for software engineering teams dedicated to solving extreme-scale problems in solid-Earth science

4. Strategic alliance between NSF and DOE in exascale computing

End